

Direct photons in d+Au and p+p collisions

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Abstract. Results are presented from an ongoing analysis of direct photon production with the STAR experiment at RHIC. The direct photon measurement in d+Au collisions and the π^0 spectrum in p+p collisions are found to be in agreement with NLO pQCD calculations.

1. Introduction

Direct photons are an interesting tool to study the quark-gluon plasma (QGP) created in ultra-relativistic heavy-ion collisions (see [1] for a recent review). These photons are directly produced throughout the various stages of the collision and do not originate from hadronic decays.

It is expected that thermal photons are radiated by the electric charges in the QGP and the hadron gas which is formed in the later stage of the expansion [2]. A measurement of thermal photons can thus provide information on the temperature evolution of the system.

The photons which originate from initial hard scatterings are also of interest. They allow to check scaling assumptions of initial parton densities and have to be known because they form a background to the thermal component. Furthermore, prompt photons may be used to tag recoiling jets. These tagged events will allow jet quenching studies with a calibrated partonic probe [3].

At RHIC there is the possibility to study direct photon production not only in Au+Au, but also in p+p and d+Au collisions. Direct photon production in p+p collisions can serve as a precision test of pQCD, while in d+Au collisions it can be used to investigate nuclear effects in the gold core. Both measurements will constitute a necessary reference to interpret the photon results obtained from Au+Au collisions.

2. Analysis

The data presented here were taken with the STAR detector [4] in the 2003 d+Au and 2005 p+p run at RHIC, both at $\sqrt{s_{NN}} = 200$ GeV. The main detectors for this analysis are the Barrel Electromagnetic Calorimeter (BEMC) [5], the Barrel Shower

Maximum Detector (BSMD) [5], and the Time Projection Chamber (TPC) [6]. In order to enhance the raw particle yield at high transverse momentum (p_T) an online trigger selected events with a high transverse energy deposition in a single BEMC cell. More details on this direct photon analysis are given in [7].

This analysis aims to measure the direct photon yield by means of a statistical subtraction of the hadronic decay background. The largest contribution to this background comes from the decay $\pi^0 \rightarrow \gamma\gamma$. It is therefore essential to measure the pion spectrum with high precision.

Inclusive photon candidates were identified by a clustering algorithm based on the energy measured in the BEMC and on the lateral shower profile measured in the BSMD. The latter is essential to resolve the two π^0 decay photons at high p_T . To identify neutral clusters and decrease hadronic background, a charged particle veto (CPV) is provided by rejecting clusters with a pointing TPC track.

The yield of decay photons has been determined from a Monte-Carlo simulation which had a fit to the measured pion spectrum as input. Since there are no measurements available for η and $\omega(782)$ yields, it was assumed that their transverse mass (m_T) spectra are the same as that of the π^0 scaled by a constant which was taken from literature [8, 9]. The result of the simulation is shown in Figure 1. Other possible contributions to the decay background, such as η' and K_s^0 , were found to be negligible.

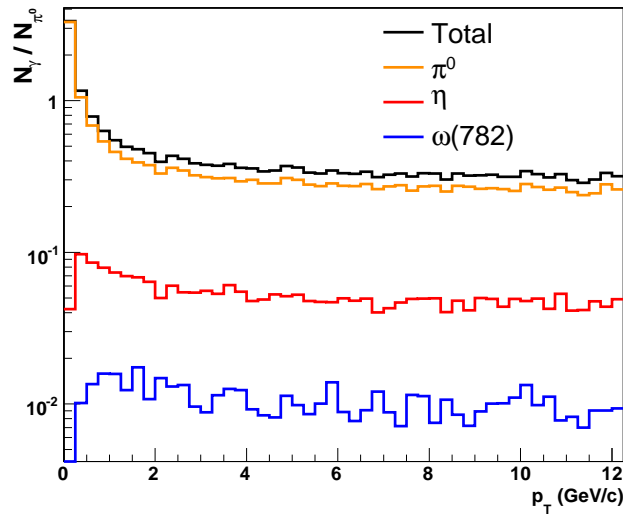


Figure 1. The number of photons per input pion N_γ/N_{π^0} from hadronic decays versus p_T , obtained from a simulation described in the text.

Showers from neutral hadrons and especially anti-neutrons can be misidentified as photons. To correct for this contamination of the inclusive photon yield a GEANT simulation of the detector was used which had the proton and anti-proton spectra as an input [10]. The data have been corrected for reconstruction and trigger efficiencies, limited acceptance, photon conversions in the detector material in front of the BEMC, and the inefficiency of the CPV.

3. Results and outlook

The direct photon spectrum follows from the subtraction of the large decay background from the inclusive spectrum. In order to do this, systematic errors need to be well under control. We therefore use the double ratio

$$R = \frac{(\gamma/\pi^0)_{\text{measured}}}{(\gamma/\pi^0)_{\text{decay}}} = 1 + \frac{\gamma_{\text{direct}}}{\gamma_{\text{decay}}} \quad (1)$$

where the numerator is the point by point ratio of the measured inclusive photon spectrum to the neutral pion spectrum and the denominator is the number of simulated decay photons per input pion shown in Figure 1. In this ratio many systematic uncertainties, which are common to neutral pion and inclusive photon detection will (partially) cancel.

In Figure 2, we show the p_T dependence of R obtained from $d+Au$ collisions. The double ratio is consistent with a pQCD calculation [11] based on the CTEQ6M parton density functions [12], the GRV parton-to-photon [13], and the KKP parton-to-pion fragmentation functions [14] as shown for three different factorization scales by the curves in Figure 2. The parton-to-photon fragmentation functions are included since this analysis does not make use of an isolation cut for the photon candidates.

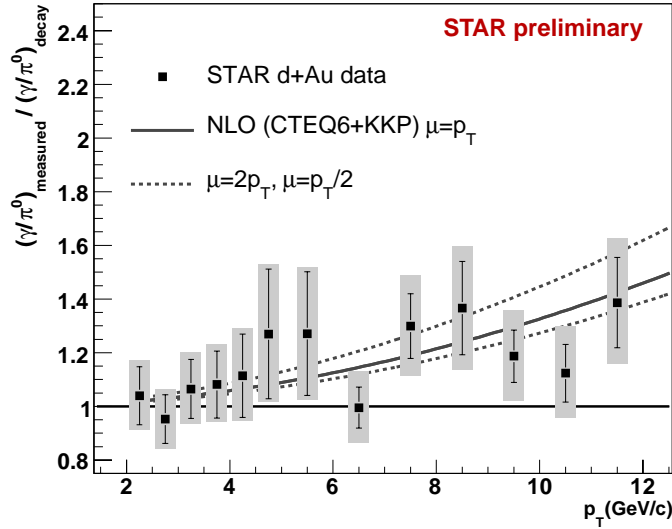


Figure 2. The double ratio R , defined in equation (1), as a function of p_T . The error bars (grey boxes) indicate the statistical (total) error on the data points. The full line is a pQCD calculation for $p+p$ collisions using the CTEQ6M parton densities, the KKP parton-to-pion, and the GRV parton-to-photon fragmentation functions. The dashed lines show the sensitivity of the calculation to the factorization scale.

The dominant systematic error on the measurement of the π^0 yield is the uncertainty of the BEMC energy scale and is estimated to be approximately 30%. This uncertainty largely cancels when calculating the double ratio R such that the pion yield extraction (5–10%) and the statistical errors on the correction factors (5–10%) are the most important contributions to the error on R .

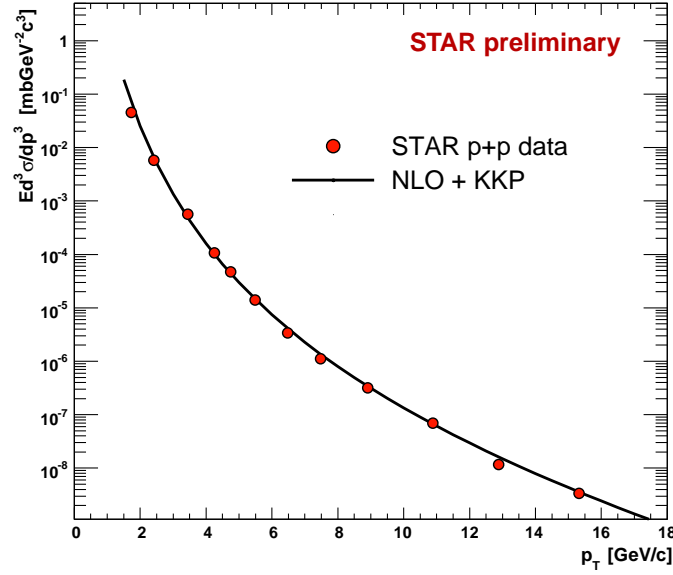


Figure 3. The differential cross-section $Ed^3\sigma/dp^3$ for inclusive π^0 production in p+p collisions at $\sqrt{s_{NN}} = 200$ GeV as a function of p_T . The data are compared to a pQCD calculation described in the text.

Figure 3 shows the π^0 cross-section in p+p collisions as a function of p_T . Details of this analysis can be found in [15]. The data is well described by a pQCD calculation in combination with the KKP set of fragmentation functions [14] which is consistent with an earlier measurement at RHIC [16].

The direct photon analysis of the 2005 p+p data set is in progress. The combined d+Au and p+p results will provide insight into nuclear effects and form a necessary baseline to study the properties of the QGP using direct photon measurements in Au+Au collisions.

4. References

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